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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

00204788.4

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

I.L.C. HATTEN-HECKMAN

DEN HAAG, DEN
THE HAGUE, 28/08/01
LA HAYE, LE

EPA/EPO/OEB Form 1014 - 02.91

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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.: 00204788.4
Demande n°:

Anmeldetag:
Date of filing: 22/12/00
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
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Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Method of analyzing a data set comprising a volumetric representation of an object to be examined

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
/

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/TR
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

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Method of analyzing a data set comprising a volumetric representation of an object to be examined

The present invention relates to a method of analyzing a data set of an object to be examined, which data set comprises voxels of at least a first and a second type.

Such a volumetric representation of the object can be acquired by means of various techniques. Some examples include: 3D X-ray rotational angiography, computed tomography, magnetic resonance imaging or magnetic resonance angiography. The object typically represents a patient to be examined.

The international patent application EP00/09505 (PHN 17.678) of the same applicant (not yet published) relates to a method of the type mentioned above. This method concerns the determination of the volume of an aneurysm in a blood vessel. According to the method described in the international patent application EP00/09505, a self-adjusting probe is defined for analysis of the data set. This requires a lot of expert interaction, which is a burden, since the analysis is often performed real-time during vascular surgery.

The invention aims at providing a method of the type described above, which requires less expert interaction.

Thereto the method according to the invention comprises the following steps:

a) classifying the voxels as voxels of the first, second or further types;
b) determining which of the voxels of the first type are boundary voxels lying adjacent to voxels of the second or further types;
c) assigning a data value to each voxel of the first type representing a measure of the distance of said voxel to the nearest boundary voxel;
d) classifying the voxels of the first type with a distance data value above a predetermined threshold as aberration voxels.

The method according to the invention allows for a quick semi-automatic determination of the voxels defining the aberration.

In a preferred embodiment the method further comprises the following steps:

e) determining which of the aberration voxels are boundary aberration voxels lying adjacent to voxels of the first type;

f) adding a number of voxels of the first type forming a shell with a certain thickness to the aberration voxels.

The number of voxels defining the aberration can now be determined with a greater accuracy.

Preferably step f comprises the steps of:

f1. assigning a data value to each voxel of the first type representing a measure of the distance of said voxel to the nearest boundary aberration voxel;

f2. classifying the voxels of the first type with a distance data value less than or equal to a predetermined ceiling value as aberration voxels.

In an embodiment the volume of the aberration is computed by determining the sum of all aberration voxels; and multiplying the sum of the aberration voxels by the volume of a single voxel to determine the volume of the aberration.

According to an elegant embodiment of the method according to the invention said distance data values are computed by means of a distance transform function. It is noted that the distance transform function is known per se in a field different from that of the present invention, namely the field of computer vision, where the distance transform function is used for object recognition based on pictures. The distance transform function is for instance described in the paper "Distance transformations in arbitrary dimensions" by G. Borgefors, Computer Vision, Graphics and Image Processing, Vol. 27, pages 321-345, 1984.

The threshold and/or ceiling value can be set by the user. To further reduce the necessary expert interaction the threshold and/or ceiling value can alternatively be computed based on a histogram of distance data values.

To further enhance the accuracy of the computation of the volume of the aberration according to another embodiment the method according to the invention comprises the steps of:

defining a tubular structure of voxels of the first type piercing through the aberration; and determining the number of voxels of the tubular structure and subtracting said number of the number of aberration voxels. Preferably the method further comprises the steps of:

a. Classifying all boundary aberration voxels as potential tubular structure voxels;

b. Selecting a starting point out of the potential tubular structure voxels;

c. Selecting an end point out of the potential tubular structure; and

d. Connecting the starting point to the end point thus defining the tubular structure.

The invention also refers to a computer program to carry out the method according to the invention.

The invention will be further explained by means of the attached drawings, in which:

Figure 1 shows schematically a volumetric representation of an object to be examined after application of a first embodiment of the method according tot the invention; and

Figure 2 shows the volumetric representation of figure 1 after application of a second embodiment of the method according tot the invention.

Figure 1 shows an example of a possible result of application of the present invention to an object to be examined. In this case the object is part of the vascular system of a patient. By means of well-known techniques the object is recorded and represented by means of a data set comprising volume elements (voxels). An example of such a technique is for instance described in the article “3D rotational angiography: Clinical value in endovascular treatment” , by Moret et al., published in Medicamundi, vol. 42, Issue 3, November 1998. In the present example there are generally two kinds of voxels, namely voxels of the first type, which in this case are vessel voxels, and voxels of the second type, which in this case are tissue voxels (not shown).

In figure 1 the object 1 is schematically shown comprising blood vessels 2 connected to an aneurysm 3, which is an aberration of the vessel acting as a reservoir.

Application of the method according to the invention allows for determination of the volume of the aneurysm, which is essential for successful and save medical treatment thereof.

In a first step vessel voxels are classified as voxels of the first type and tissue voxels are classified as voxels of the second type. This can be performed by means of known techniques, such as a ‘region growing algorithm’.

In a next step it is determined which of the vessel voxels lie adjacent to tissue voxels. These are referred to as boundary vessel voxels. Preferably this determination is performed by finding the face neighbors, i.e. neighbors which have one voxel face in common.

Subsequently a data value is assigned to each vessel voxel representing a measure of the distance of said vessel voxel to the nearest boundary vessel voxel. According

to the invention said distance data values are computed by means of a distance transform function.

According to the distance transform function the distance data values of the boundary vessel voxels are set at a low value, e.g. zero. For all other voxels initially a high value is chosen, for example 127. The distance transform function then computes distance data values for each voxel. An elegant way of computing the distance data value is as follows: the distance data value for a specific voxel is defined as the minimum of the distance data value of each of the neighbors of that specific voxel plus a number, e.g. one. Preferably the distance transform function is computed once for all voxels in a certain order. Next the distance transform is again computed for all voxels, but now in reversed order. In order to simplify and thus shorten the computation preferably only vessel voxels are involved in the computation. An example of the result of this computation is shown in figure 1.

Now all vessel voxels with a distance data value above a predetermined threshold are then classified as aberration voxels. The user can set this threshold interactively. Preferably the threshold should be chosen slightly greater than the radii of the connected vessels 2. As an alternative the threshold can be computed automatically, e.g. based on a histogram of distance data values. In this example let's assume that the threshold is three. All vessel voxels with a distance data value equal to or larger than three are now classified as aberration voxels. In the present example the aberration voxels are aneurysm voxels and a first estimate for the number of aneurysm voxels is now available.

In order to more precisely compute the number of aneurysm voxels the next steps are performed.

These steps largely mean that a new distance data value is computed for a select number of voxels to make sure that all boundary aberration voxels are also included. Again the distance transform function can be used for this purpose. For useful techniques and remarks to perform these steps we refer those mentioned above.

First it is determined which of the aberration voxels are boundary aberration voxels lying adjacent to vessel voxels.

Next a data value is assigned to each vessel voxel representing a measure of the distance of said voxel to the nearest boundary aberration voxel. The result of this computation is shown in figure 2.

All vessel voxels with a distance data value less than or equal to a predetermined ceiling value are now classified as aberration voxels. Preferably the ceiling value is equal to or slightly greater (e.g. by one unit) than the threshold. In this case the

ceiling value is equal to the threshold, namely three. As can be seen when comparing figure 1 and figure 2 the second computation results in a more accurate determination of the number of aneurysm voxels.

Now that the aneurysm voxels are known they can simply be summed up and multiplied by the volume of a single voxel to determine the volume of the aneurysm 3.

In the specific case of determining the volume of an aneurysm those voxels representing part of the vessel which is needed for an unrestricted blood flow between the vessels 2 should preferably not be included. To account for these voxels a tubular structure of vessel voxels piercing through the aneurysm is

This can be performed by means of the following method comprising the following steps. First all boundary aneurysm voxels are classified as potential tubular structure voxels. Out of the potential tubular structure voxels one voxel is selected as a starting point and one voxel is selected as an end point. To define the tubular structure the starting point and the end point are connected. This connection can be performed by means of known techniques, such as the so-called "self adjusting probes" mentioned above.

Based on the definition of the tubular structure the corresponding number of voxels can be determined and subtracted from the number of aneurysm voxels.

Now the method of the invention is explained a skilled person will be able to translate the steps of the method into a computer program to carry out the method.

Summarizing the invention refers to a method for analyzing a data set comprising a volumetric representation of (a part of) an object to be examined for detecting a sub object with a volume greater than the volume of surrounding sub objects and measuring the volume of said sub object. This method is especially useful in the field of medical diagnostics and treatment, where the object notably is a patient to be examined.

The invention is of course not limited to the described or shown embodiments, but generally extends to any embodiment, which falls within the scope of the appended claims as seen in light of the foregoing description and drawings

CLAIMS:

1. A method of analyzing a data set of an object to be examined, which data set comprises voxels of at least a first and a second type, said method comprising the following steps:

a) classifying the voxels as voxels of the first, second or further types;

b) determining which of the voxels of the first type are boundary voxels lying adjacent to voxels of the second or further types;

c) assigning a data value to each voxel of the first type representing a measure of the distance of said voxel to the nearest boundary voxel;

d) classifying the voxels of the first type with a distance data value above a predetermined threshold as aberration voxels.

2. A method according to claim 1, further comprising the following steps:

e) determining which of the aberration voxels are boundary aberration voxels lying adjacent to voxels of the first type;

f) Adding a number of voxels of the first type forming a shell with a certain thickness to the aberration voxels;

3. A method according to claim 2, wherein step f comprises the steps of:

f1. assigning a data value to each voxel of the first type representing a measure of the distance of said voxel to the nearest boundary aberration voxel;

f2. classifying the voxels of the first type with a distance data value less than or equal to a predetermined ceiling value as aberration voxels.

4. A method according to claim 1, 2 or 3, further comprising the steps of: Determining the sum of all aberration voxels; and multiplying the sum of the aberration voxels by the volume of a single voxel to determine the volume of the aberration.

5. A method according to one or more of the preceding claims, wherein said distance data values are computed by means of a distance transform function.

6. A method according to one or more of the preceding claims, wherein said threshold and/or ceiling value is set by the user.

7. A method according to one or more of the preceding claims 1 through 5, wherein said threshold and/or ceiling value is computed based on a histogram of distance data values.

8. A method according to one or more of the preceding claims, further comprising the steps of:
defining a tubular structure of voxels of the first type piercing through the aberration; and determining the number of voxels of the tubular structure and subtracting said number of the number of aberration voxels.

9. A method according to claim 8, further comprising the steps of:

a. Classifying all boundary aberration voxels as potential tubular structure voxels;

b. Selecting a starting point out of the potential tubular structure voxels;

c. Selecting an end point out of the potential tubular structure;

d. Connecting the starting point to the end point thus defining the tubular structure.

10. A computer program to carry out the method according to one or more of the preceding claims.

ABSTRACT:

The invention concerns a method of analyzing a data set of an object to be examined, which data set comprises voxels of at least a first and a second type, said method comprising the following steps:

a) classifying the voxels as voxels of the first, second or further types;
b) determining which of the voxels of the first type are boundary voxels lying adjacent to voxels of the second or further types;
c) assigning a data value to each voxel of the first type representing a measure of the distance of said voxel to the nearest boundary voxel;
d) classifying the voxels of the first type with a distance data value above a predetermined threshold as aberration voxels.

The invention also refers to a computer program to carry out the method according to the invention.

Fig. 1

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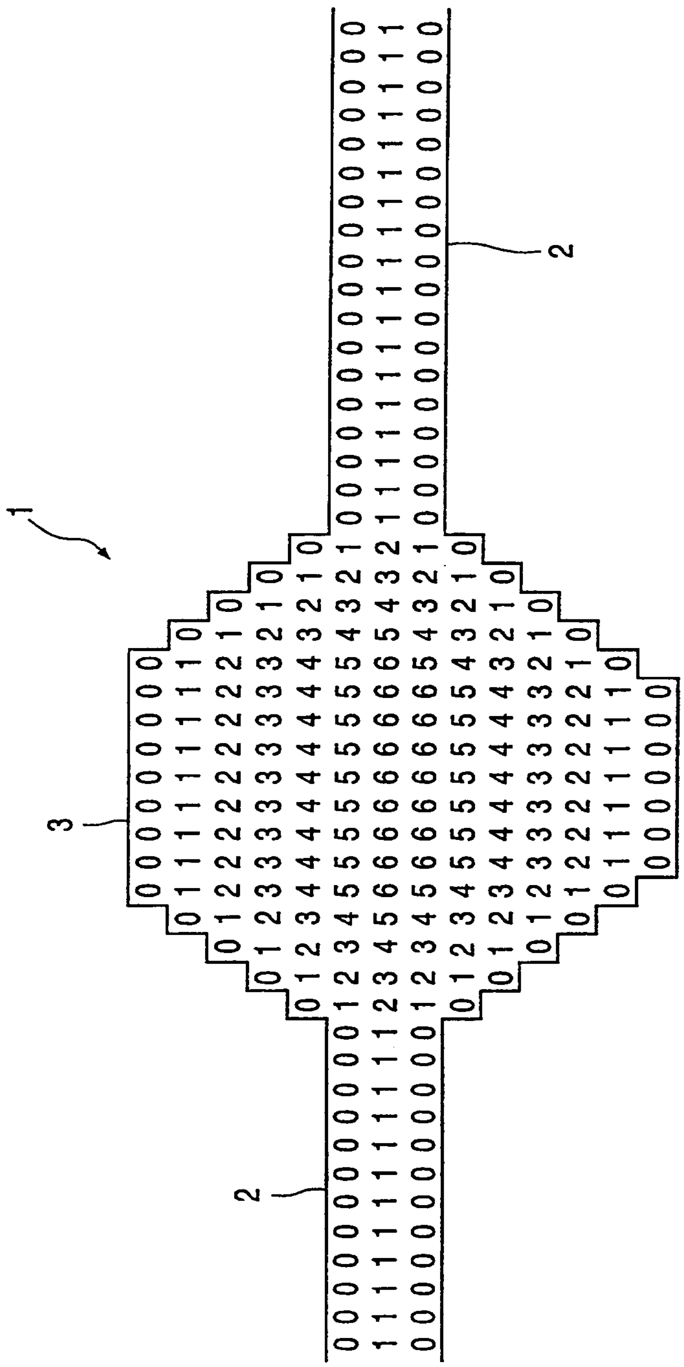

FIG. 1

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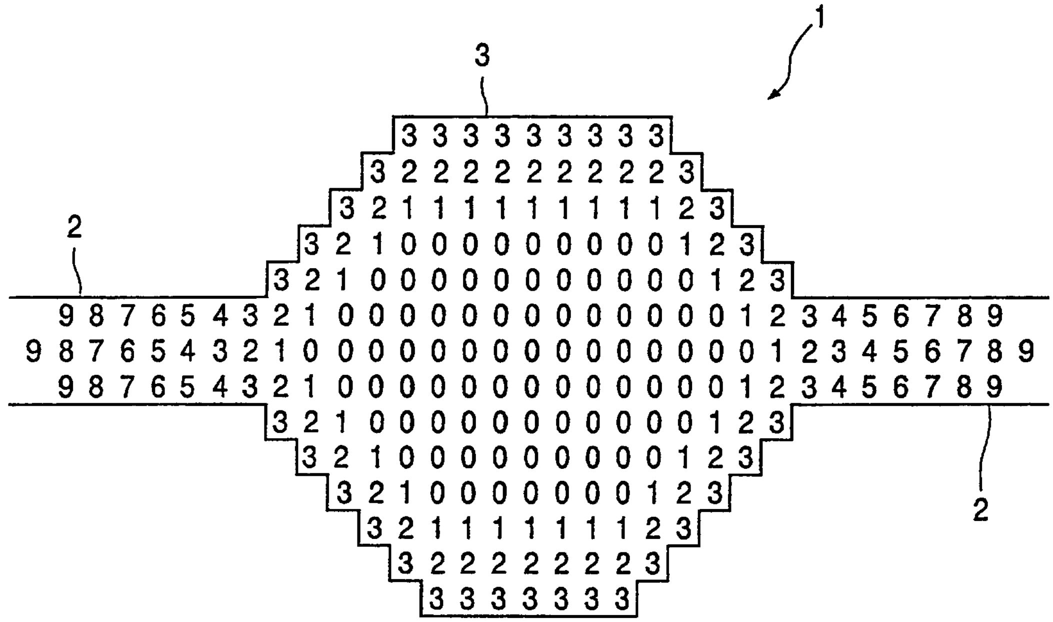
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FIG. 2